

Analysis of Inorganic Waste Material Flow for Zero Waste Achievement Scenarios on the Mataram University Campus

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Abstract: Waste management at the University of Mataram still uses the traditional scenario, namely collecting, transporting and disposing of it at the landfill so that it has not made a real contribution to reducing waste generation in Mataram City. This study aimed to determine the generation, composition, and potential for reducing inorganic waste on the Mataram University campus. Data on inorganic waste generation and its composition were collected using the load count method according to ASTM D5231-92 and SNI 19-3964-1994. The data were then processed through Material Flow Analysis (MFA) with the 3R approach. The results showed that the inorganic waste generated on the Mataram University campus reached 431.09 kg/day (0.0208 kg/person/day), and after being collected by scavengers (average 149.09 kg/day), residue of 282.01 kg/day (65.43%) was left, with the composition dominated by paper (32.78%) and plastic (32.40%). The potential for reducing inorganic waste per day reached 186.43 kg, namely through reduce (86.8 kg), recycle (98.81 kg), and reuse (0.82 kg), leaving a residue of 95.59 kg (22.17%). The new scenario for waste management with the implementation of the 3Rs approach can significantly reduce the generation of inorganic waste, thereby supporting efforts to achieve zero waste on the Mataram University campus.

Keywords: Composition; 3Rs approach; Reducing inorganic waste generation; Sorting.

Introduction

Mataram City's waste production in 2022 reached 264.21 tons/day (96,436.87 tons/year) and in 2023 experienced an increase, namely 271.69 tons/day (99,436.87 tons/year). The increase in urban waste volume partly came from non-domestic sources, namely educational areas. Mataram University is one of the largest state universities, with 12 faculties, with a total academic community of 20,697 people in 2024. The academic community of Mataram University continues to grow, especially due to the increase in new students (Widiyanti *et al.*, 2020; SIPSN, 2023; PDDIKTI, 2025).

Mataram University did not have an inorganic waste management system in an

effort to reduce waste generation. The campus waste management system only includes collection, transportation, and direct disposal to the landfill in Kebon Kongok, West Lombok. This problem raises the risk of increasing waste generation, which is followed by increasing operational costs and increasingly complex infrastructure requirements. Efforts to reduce waste generation require data on the waste generation itself and its composition. Waste generation data, especially inorganic components and their composition, can be processed through 3Rs-based material flow analysis to produce a new scenario model for managing waste (Rakhman *et al.*, 2022; Rahayu *et al.*, 2022).

Based on the background of the problem above, this research was conducted with the

aim of determining the generation, composition, and potential for reducing inorganic waste on the Mataram University campus. Data analysis in this study was also directed at producing a new scenario for waste material flow, in order to achieve zero waste on the Mataram University campus.

Materials and Methods

This research was carried out in stages which included a preliminary survey to determine the time, place and sampling technique, data collection and data analysis. The general outline of the research workflow can be seen in Figure 1.

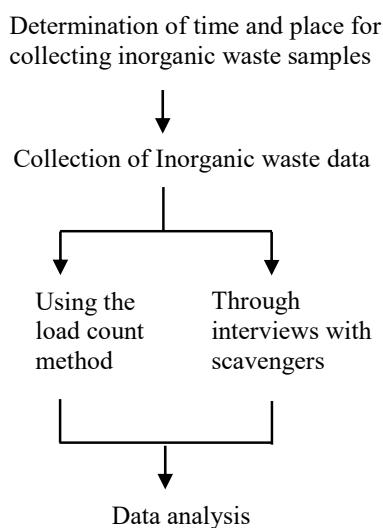


Figure 1. Work flow chart of the study of inorganic waste material flow on the Mataram University campus.

Time and Place of Sampling

This study was conducted over 15 working days from February to March 2025 on the campus of the University of Mataram. Sampling was conducted daily for 8 consecutive working days using garbage trucks that had collected waste from each source point from 12 locations (in this case, the faculties) (Figure 2).

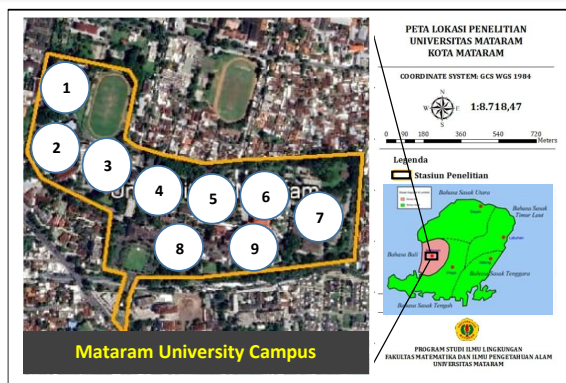


Figure 2. Locations for collecting inorganic waste samples on the Mataram University campus.

Data Collection Procedures

Inorganic waste generation

Inorganic waste sampling was carried out using the Load Count Analysis method with a technique adapted from Widiyanti & Hadi (2022). The waste collected in the garbage trucks from 9 source points was sorted to separate the inorganic components from the organic waste components. The volume of inorganic waste components is measured in m³ units and then converted into liters (1 m³ = 1000 L). Data on the number of campus communities as sources of waste was taken from 9 source points, in this case 9 faculties at the University of Mataram.

Take 1 m³ of inorganic waste sample into a 1 m³ (1000 L) compaction box to measure its weight in kg. The sample density factor was calculated using the following formula (Equation 1):

$$DF \text{ (kg/L)} = \frac{\text{Garbage weight (kg)}}{\text{Volume of compaction box(1000 L)}} \dots\dots\dots (1)$$

where,
 DF = density factor

This density factor was used to convert units of waste volume (L) into units of waste weight (kg). The daily weight of inorganic waste generated was calculated using the following formula (Equation 2):

$$\text{Waste generation (kg/person/day)} = \frac{\text{Total volume of inorganic waste(L) x Density factor (kg/L)}}{\text{Number of people from the campus community x days}} \dots\dots\dots (2)$$

In parallel with the collection of waste data mentioned above, data was also collected on inorganic waste collected by scavengers through interviews and direct observation (measuring the weight of waste collected per day).

Composition of inorganic waste

Determination of the composition of inorganic waste components was carried out in accordance with the Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM D5231-92). Take 12 kg of inorganic waste samples and then sort them according to SNI 19-3964-1994 (DPU Bandung, 2025) into 9 components, namely paper, cardboard, wood, cloth/textile, rubber/leather, plastic (PETE, HDPE, PVC, LDPE, PS, multilayer plastic, other), metal, glass, and B3 waste. Each component (and sub-component, especially for plastic) was measured by weight in kg.

Potential for reducing inorganic waste

An analysis of the potential for reducing inorganic waste production was conducted on the composition data of inorganic waste components using a potential table, which employs the 3R approach: reduce, reuse, and recycle. Each inorganic waste component was mapped for its reduction potential through the application of the 3Rs.

Determination of a new scenario model for inorganic waste management

The new waste management scenario was systematically compiled from upstream to downstream through Material Flow Analysis (MFA) of inorganic waste generation data, its composition, reduction potential and inorganic waste collected by scavengers. The final waste residue after reduction (output) was calculated using the following formula (Equation 3):

$$\Sigma \text{Output} = \Sigma \text{Input} - \text{Change in stock} \dots (3)$$

Where,

Output: Final waste residue

Input: Waste generation

Change in stock: Waste reduction by 3R and scavengers

Results and Discussion

Inorganic waste generation

The production of inorganic waste observed during 8 working days on the Mataram University campus ranged from 345.47 to 509.62 kg/day (average = 431.09 kg/day). The average weight of inorganic waste collected by scavengers was 149.09 kg/day, leaving an inorganic waste residue of 282.02 kg/day (Table 1).

Table 1. Inorganic waste production observed during 8 working days on the Mataram University campus

Day	Inorganic waste (kg/day)		
	Residue after scavenging	The scavenged	Total
Mon	213.23	149.09	362.32
Tues	356.97	149.09	506.06
Wed	322.73	149.09	471.82
Thu	360.53	149.09	509.62
Fri	230.17	149.09	379.26
Mon	298.82	149.09	447.91
Tues	196.38	149.09	345.47
Wed	277.24	149.09	426.33
Average	282.02	149.09	431.09

Referring to the academic community population of the University of Mataram campus of 20,697 people (students, lecturers and staff), as a source of waste generation, which was assumed to be a constant amount every working day, the inorganic waste generation on the campus was around 0.0167 to 0.0245 kg/person/day (average = 0.0208 kg/person/day). These results showed that the generation of inorganic waste on the Mataram University campus from day to day during the week shows fluctuating changes, but with a downward trend from the beginning of the week to the end of the week (Figure 2).

On days when waste generation was relatively high, the increase in waste production was dominated by inorganic waste components from cardboard and paper. The trend of increasing or decreasing waste generation from the beginning to the end of the week with almost the same pattern in each month of one semester may be related to the number of waste producers from the campus

academic community, such as students, lecturers, and education staff. Meanwhile, fluctuations in waste generation were more likely to be influenced by other types of activities, such as the arrival of guests for seminars, public lectures, and anniversary ceremonies for faculties or study programs, which vary both according to time and location.

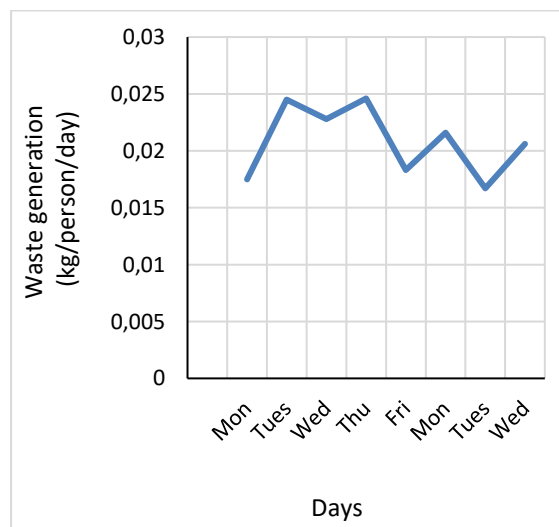


Figure 2. Inorganic waste generation during 8 working days of observation at the University of Mataram campus

The inorganic waste generation at Mataram University, namely 0.0208 kg/person/day, is classified as below average. The average inorganic waste generation for the domestic environment in Indonesia before processing was around 0.1224 kg/person/day. It has also been previously reported that inorganic waste generation on other university campuses is still below average, such as 0.05 kg/person/day on the Respati University campus in Yogyakarta, 0.03 kg/person/day on the Bakrie University campus in Jakarta (Arindya et al., 2016; Larasati & Fitria, 2020; Pascawati et al., 2023).

Composition of inorganic waste

The inorganic waste generated on the Mataram University campus was dominated by paper and plastic (38.52 and 37.34%) followed by lower percentages of metal, cardboard, rubber, glass, cloth and wood respectively (Figure 3).

The results above indicate that inorganic waste, particularly paper and plastic, had significant potential as a target for waste reduction. Other components, such as metal, cardboard, rubber, glass, and wood, can also be

targeted for reduction, but with much lower potential (Arindya et al., 2016; Manin et al., 2023; Novitasari et al., 2024).

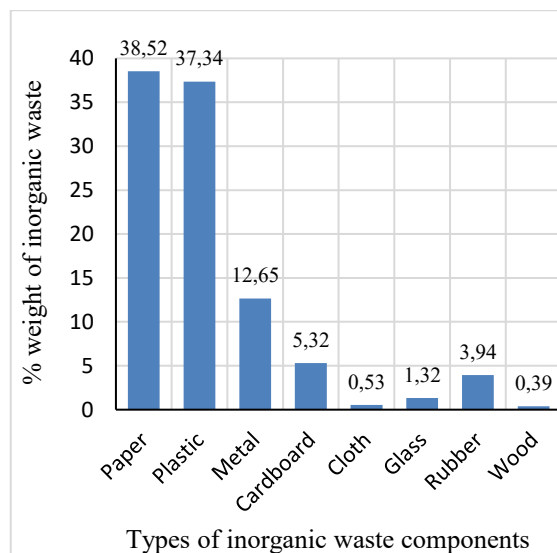


Figure 3. Composition of inorganic waste components on the University of Mataram campus

Potential for reducing inorganic waste

The results of the analysis of waste reduction through the 3R approach showed that the potential for waste reduction on the campus could reach 186.43 kg (66% of the initial 282.02 kg residue or 43.25% of the total inorganic waste on campus) leaving a final residue of 95.59 kg (34% of the initial residue or 22.17% of the total inorganic waste produced on the Mataram University campus before being collected by scavengers) (Table 2) (Figure 4).

The potential for reducing inorganic waste through limiting the use of inorganic waste reached 86.8 kg (31%) in the form of disposable cups, mineral water bottles, LDPE plastic bags, styrofoam containers and PVC mica. The use of plastic cups and bottles can be limited by using tumblers. The use of plastic shopping bags can be limited by using tote bags, which are both reusable and environmentally friendly. Styrofoam and PVC mica containers can be limited by using biodegradable boxes made from banana stems and sugar cane (Manin et al., 2023; Novitasari et al., 2024; Sunaryo & Isaeni, 2025).

Table 2. Potential for reducing inorganic waste (kg) through the 3Rs approach for the Mataram University campus

Waste reduction methods	Type of inorganic waste components (kg)									
	Cangkir plastik	Botol plastik	Kantong plastik	Wadah styrofoam	Mika	Total				
Reduce										
Exist	35.21	11.69	18.64	18.2	3.06	86.8				
Potential	35.21	11.69	18.64	18.2	3.06	86.8				
Residue	0.00	0.00	0.00	0.00	0.00	0.00				
Recycle	Kertas	Logam	Kardus	Plastik multilayer	Karet sandal	Kaca	Kayu	Kain	Total	
Exist	108.62	35.67	15.02	12.21	11.1	3.71	1.11	6.96	194.4	
Potential	43.45	28.58	6.01	6.11	11.1	2.6	0.96	0	98.81	
Residue	65.17	7.09	9.01	6.1	0	1.11	0.15	6.96	95.59	
Reuse	Botol HDPE	Total								
Exist	0.82	0.82								
Potential	0.82	0.82								
Residue	0.00	0.00								

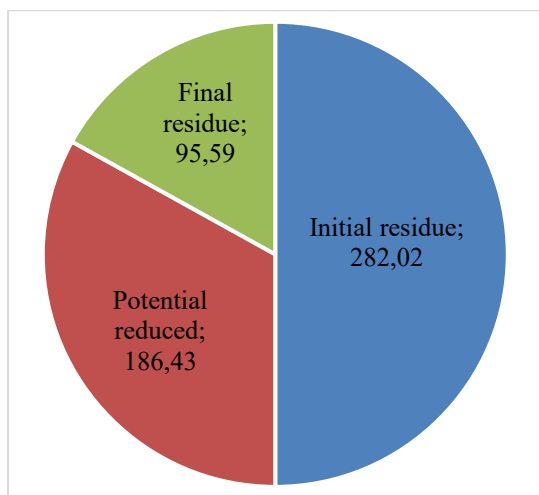


Figure 4. Potential reduction in inorganic waste residue produced (kg/day) on the University of Mataram campus

The potential for reducing inorganic waste through recycling efforts reached 98.81 kg (50.83% of 194.40 kg of existing waste) leaving 95.59 kg (49.17%) of residue. The total weight of the residue comes from 108.62 kg of paper, of which 43.45 kg can be recycled, 35.67 kg of metal, of which 28.58 kg can be recycled, 15.02 kg of cardboard, of which 6.01 kg can be recycled, 12.21 kg of multilayer plastic waste, of which 6.11 kg can be recycled, 11.10 kg of

rubber sandals, all of which can be recycled, 3.71 kg of glass, of which 2.6 kg can be recycled, 1.11 kg of wood, of which 0.96 kg can be recycled, and 6.96 kg of cloth, all of which were residues because they cannot be recycled.

Recycling paper waste was the most potential solution to address the paper waste problem. Paper waste is a relatively readily available, affordable, and environmentally friendly raw material for the recycling industry. Cans had the potential to be recycled into raw materials for can making. Some of the advantages of used cans as raw materials for cans are that they are lighter than steel, easy to shape, tasteless, odorless, non-toxic, can withstand gas entry, and have good thermal conductivity. Unused cardboard can be utilized as supporting materials in various business opportunities, one of which is by using cardboard as a growing medium for mushrooms. Multilayer plastic can be used as an additional material for making concrete blocks, thus creating a circular economy (Mulyadi & Halawa, 2013; Muchangos *et al.*, 2017; Widiani *et al.*, 2020; Saputra & Fauzi, 2022).

Rubber waste can be recycled into an additional ingredient for asphalt production. The addition of rubber waste to asphalt road

pavement construction offers numerous benefits, including a more durable pavement surface, increased braking grip, and resistance to cracks caused by excessive deflection and fatigue. Glass waste can be utilized when recycled as a partial sand substitute for concrete. This increases the tensile strength of this concrete compared to conventional concrete. Wood waste can be recycled into charcoal or briquettes, which have a higher calorific value than wood in its original form, thus producing approximately twice the energy (Purnomo & Hisyam, 2014; Sari *et al.*, 2022; Ali *et al.*, 2024).

Reducing inorganic waste through reuse can only be done for HDPE plastic waste from shampoo bottles, which reached 0.82 kg (0.29%). According to Ristya (2020); Solahudin *et al.* (2025), HDPE plastic bottles can be reused for refilling or reused directly for either the same or a different function. Although the amount is not too significant, the presence of HDPE plastic still has an impact because it is difficult to decompose naturally.

The current inorganic waste generation on the Mataram University campus was the result of waste management that still uses the old paradigm, namely collection and transportation without prior sorting and direct disposal to the landfill. Inorganic waste generation can be reduced through the implementation of the 3R approach (reduce, recycle, and reuse), which emphasizes the importance of waste sorting. The initial stage of sorting is the separation of organic

and inorganic waste. The next stage of sorting is the separation of waste components into sub-components that can then be grouped based on their reduction potential through the application of the 3R. The success of the 3R implementation is determined not only by the condition of the inorganic waste components produced, but also by the support of waste generators. Therefore, awareness and knowledge of waste generators regarding waste sorting before disposal and saving by limiting the use of single-use materials need to be increased. These efforts on campus can be carried out through outreach in the form of public lectures, seminars, or workshops (Widiyanti & Hadi, 2022; Adam & Claretta, 2023; Pascawati *et al.*, 2023; Rahsia *et al.*, 2024).

Flow of inorganic waste material on the University of Mataram campus

Of the total 341.01 kg of inorganic waste generated daily on the University of Mataram campus, 149.09 kg is collected by scavengers, leaving 282.02 kg of inorganic waste. Currently, this remaining inorganic waste is managed using the old paradigm of collecting, transporting, and disposing of it at the landfill. The current flow diagram of inorganic waste on the University of Mataram campus can be seen in Figure 5. Meanwhile, the new scenario for the flow of inorganic waste materials for the campus can be seen in Figure 6.

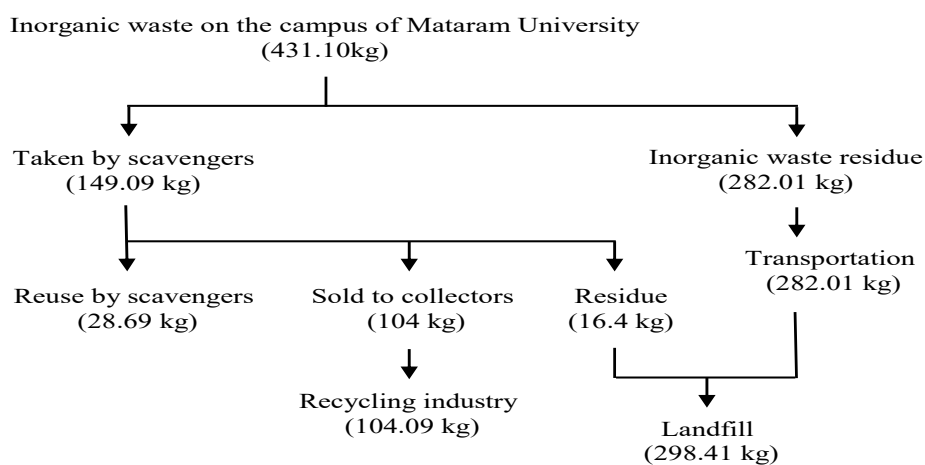


Figure 5. Diagram of the current flow of inorganic waste material on Mataram University campus

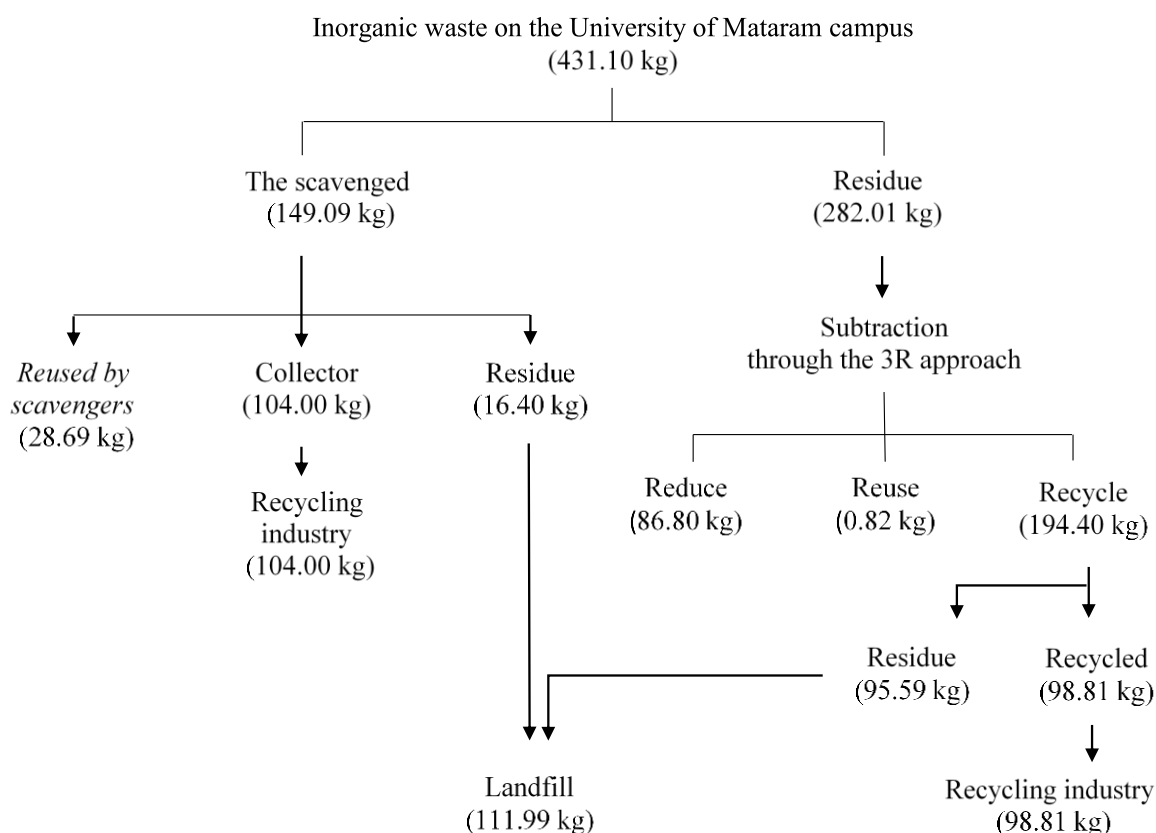


Figure 6. Diagram of the inorganic waste material flow scenario by applying the 3R approach for the Mataram University campus.

The inorganic waste generated on campus comes from the campus academic community (students, lecturers, and administrative staff). Most of the inorganic waste collected by scavengers still has a market value (plastic, paper, cardboard, and metal waste). Approximately 104 kg of waste is distributed to collectors, which then enters the recycling industry. The recycling industry also leaves behind approximately 16.4 kg of unusable residue.

By observing the current flow of inorganic waste material on the Mataram University campus, it can be seen that there is no waste reduction mechanism other than that carried out by scavengers, so that the inorganic waste residue that must be disposed of at the landfill is still quite large. Of the inorganic waste generation of 431.1 kg/day, only 149.09 kg (34.59%) was reduced by scavenger activities, and most of the rest (282.02 kg or 65.41%) was still directly disposed of at the landfill. This indicated that waste management based on reduction at the

source had not been running optimally, so that a more effective and systematic strategy update is needed by implementing the 3Rs approach.

The results of the waste reduction analysis confirmed that the implementation of the 3R approach is very significant in reducing the generation of inorganic waste. Of the total inorganic waste generation of 431.1 kg, only 95.59 kg (22.17%) of residue was disposed of in the landfill. Previously, where waste management without the implementation of 3R and inorganic waste reduction only occurred due to the activities of scavengers, the residue that had to be disposed of in the landfill was 282.01 kg (65.43%). Based on the results of this analysis, a new scenario for the flow of inorganic waste material for the University of Mataram campus can be built (Figure 6).

With the new scenario of inorganic waste material flow mentioned above, the inorganic waste residue on the campus of Mataram University showed a significant reduction, namely from 282.02 kg (65.42% of the total

431.1 kg of inorganic waste on campus) to 95.59 kg (22.17%). The advantage of this new scenario of inorganic waste material flow is that it can not only reduce the generation of inorganic waste, but also provide added economic value, namely being able to shift the status of the management burden for 186.43 kg (66.11% of the initial 282.02 kg of residue) of inorganic waste into a status of economically valuable benefits through the application of 3Rs, as described above.

With this added value, the reduction of inorganic waste generation can be encouraged to run sustainably on the University of Mataram

Conclusion

The inorganic waste generation on the Mataram University campus reached 431.09 kg/day (0.0208 kg/person/day), and after being collected by scavengers, the initial residue was 282.01 kg/day (65.43%), with the composition dominated by paper (32.78%) and plastic (32.40%). The potential reduction of inorganic waste through the implementation of 3Rs reached 186.43 kg, leaving a final residue of 95.59 kg (22.17%). The new waste flow scenario with the implementation of 3R can significantly reduce inorganic waste generation and greatly supports efforts to achieve zero waste on the University of Mataram campus.

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campus. However, the support of the campus academic community as the main source of waste generation is still needed, so that the waste management strategy with this new waste material flow scenario can be implemented optimally. Overall waste reduction efforts by managers with a systematic and optimal 3R approach in order to achieve zero waste on the University of Mataram campus will be realized if supported by high awareness and responsibility from the campus academic community as the main source of waste generation.

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